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(54) TURBINE ENGINE VARIABLE AREA VANE

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F01D 17/16 (2006.01)

(52) **U.S. Cl.**

CPC ***F01D 17/162*** (2013.01); *F05D 2260/202* (2013.01)

(58) **Field of Classification Search**

CPC F01D 17/162; F05D 2260/202
USPC 415/208.2
See application file for complete search history.

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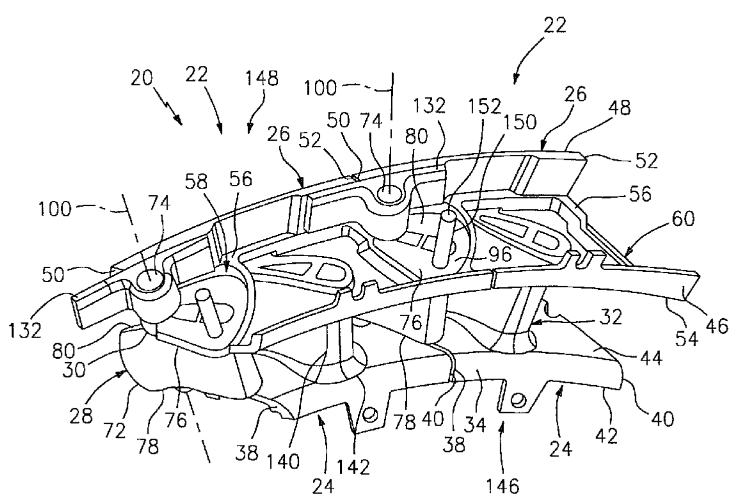
(57) **ABSTRACT**

A turbine engine stator vane is provided that rotates about an axis, and includes an airfoil, a flange and a shaft. The airfoil extends axially between a first airfoil end and a second airfoil end. The airfoil includes a concave side surface, a convex side surface and a cavity. The concave and the convex side surfaces extend between an airfoil leading edge and an airfoil trailing edge. The cavity extends axially into the airfoil from a cavity inlet in an end surface at the second airfoil end. The flange is connected to the second airfoil end. The flange extends circumferentially around at least a portion of the cavity inlet, and radially away from the concave and the convex side surfaces to a distal flange edge. The shaft extends along the axis, and is connected to the second airfoil end.

20 Claims, 6 Drawing Sheets



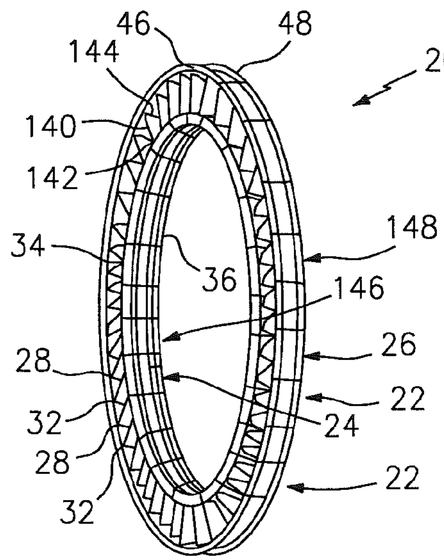

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FIG. 1

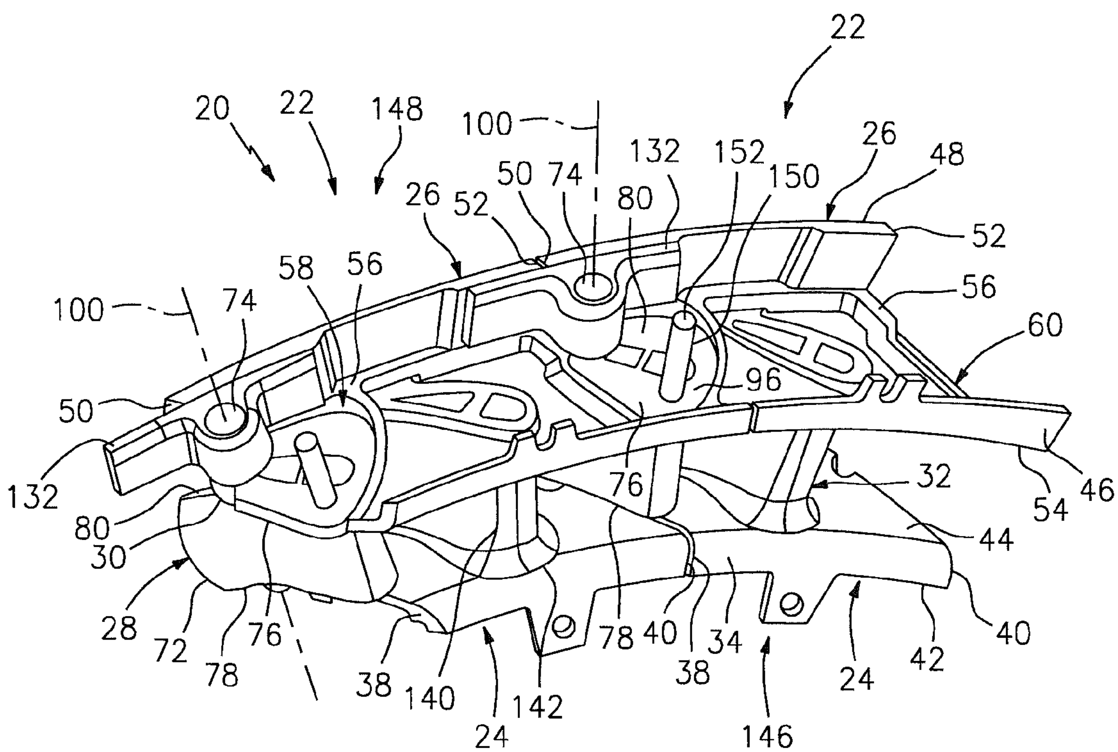
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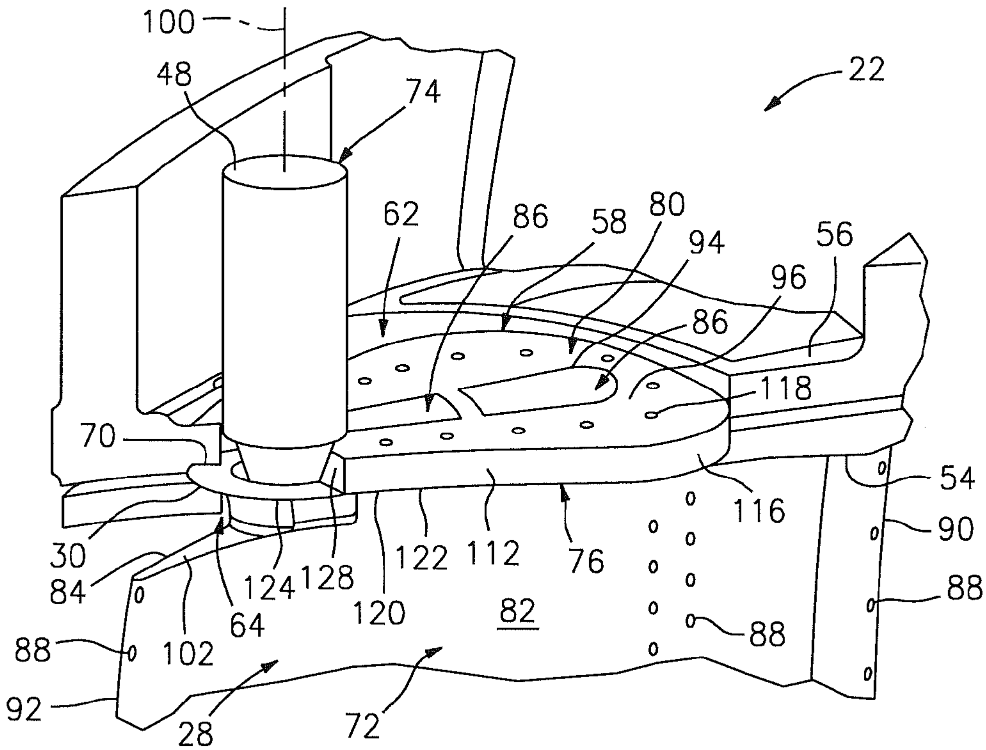
FIG. 2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128
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120
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64
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102
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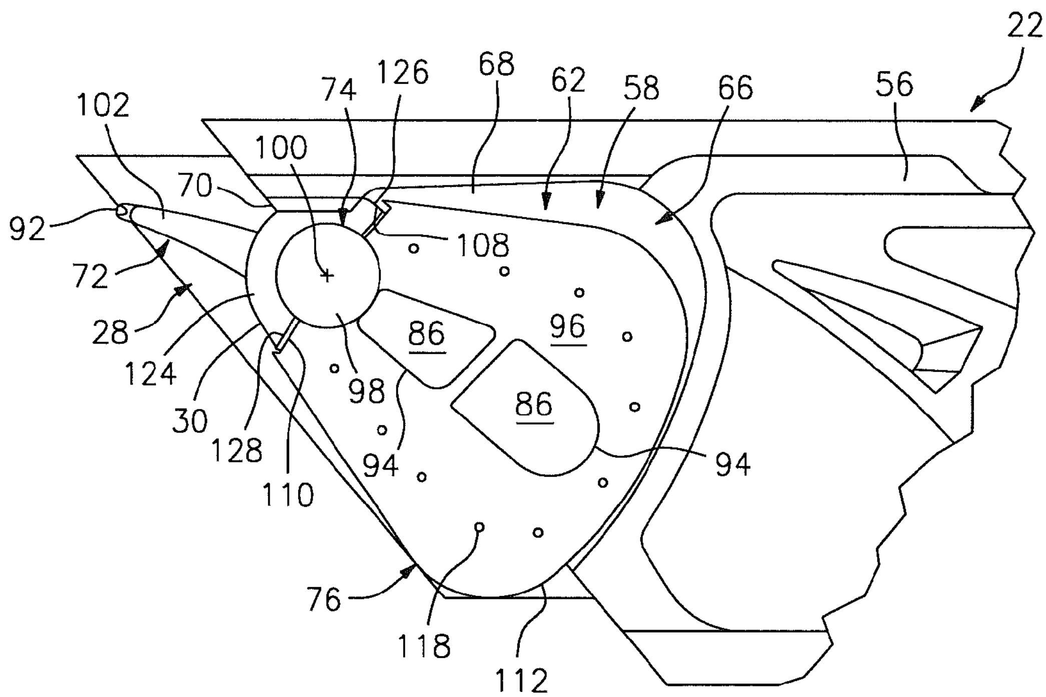
92
28
72

FIG. 3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102
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76
118
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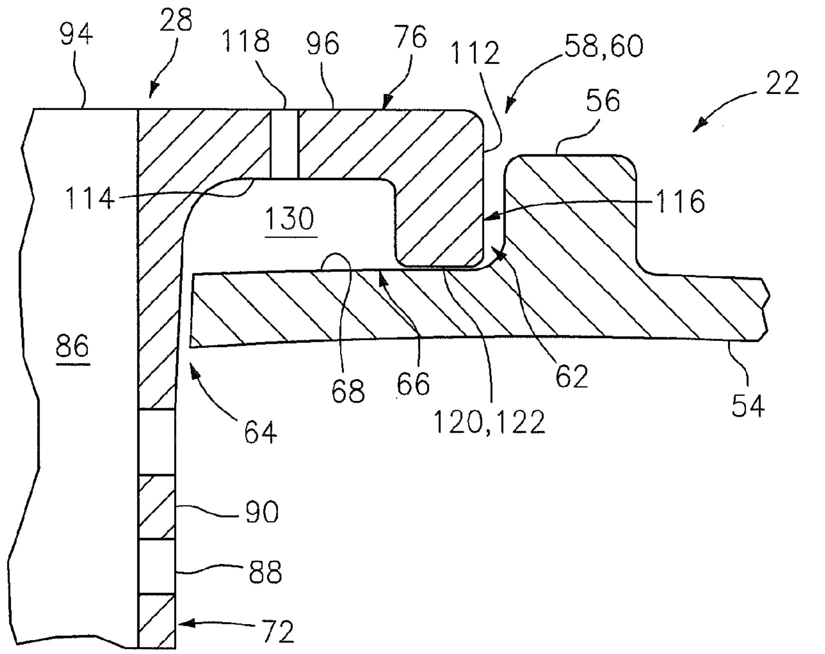
FIG. 4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76
112
58,60
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114
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66
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120,122
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64
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88
72

FIG. 5

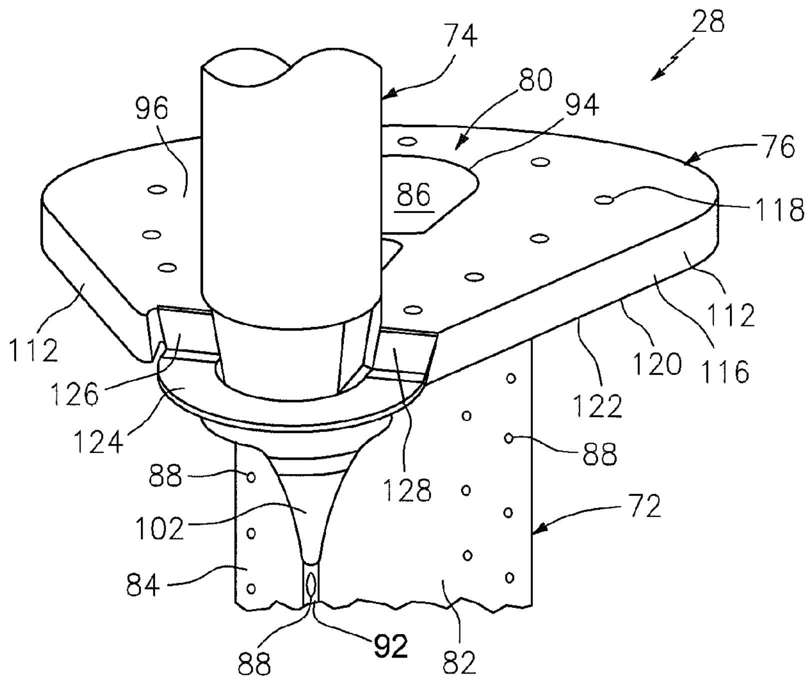
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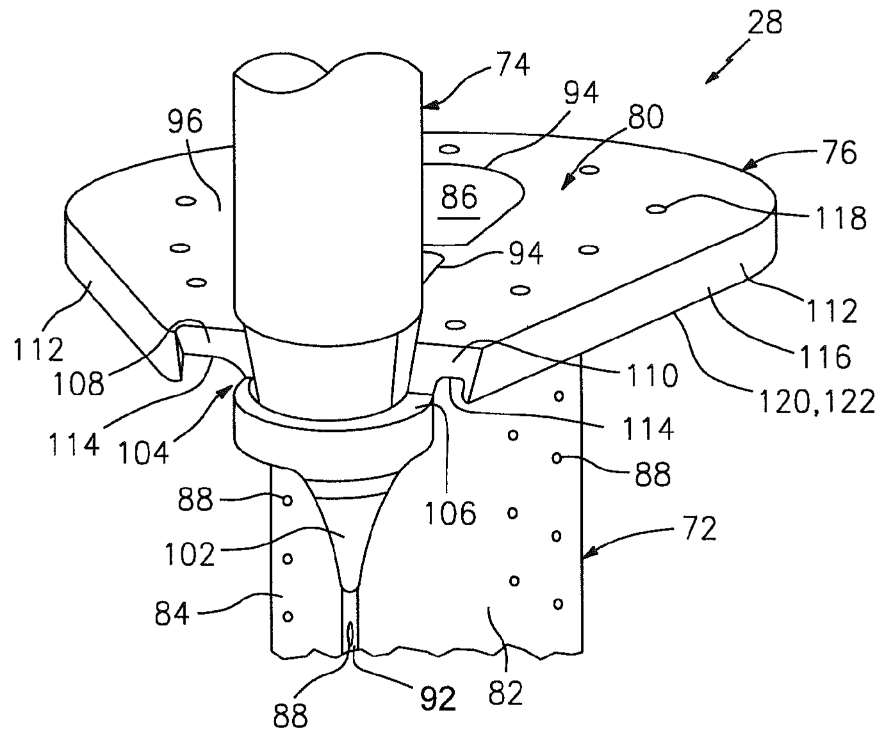
FIG. 6



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120,122
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104
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106
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92
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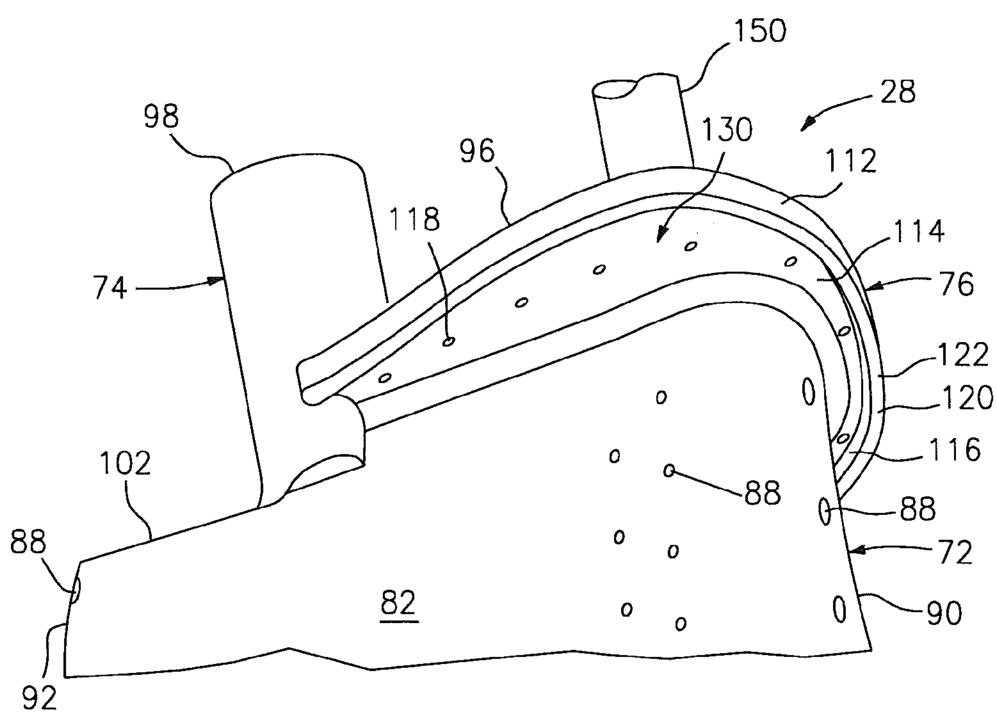
FIG. 7



150
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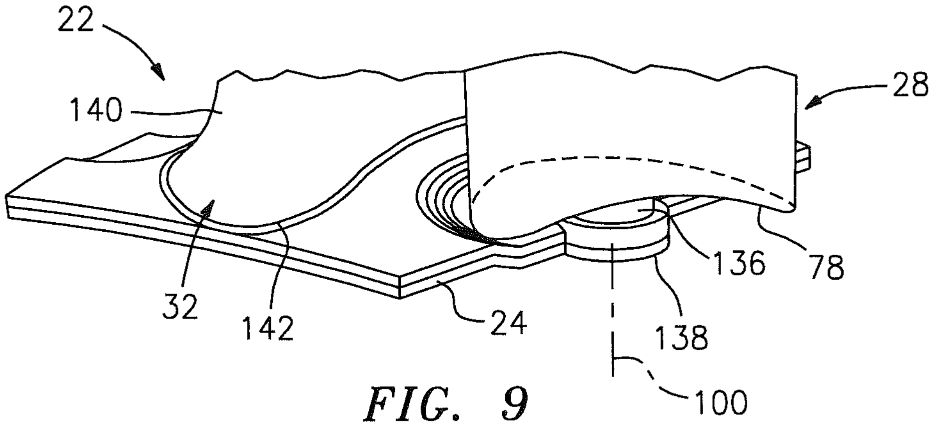
FIG. 8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100

FIG. 9

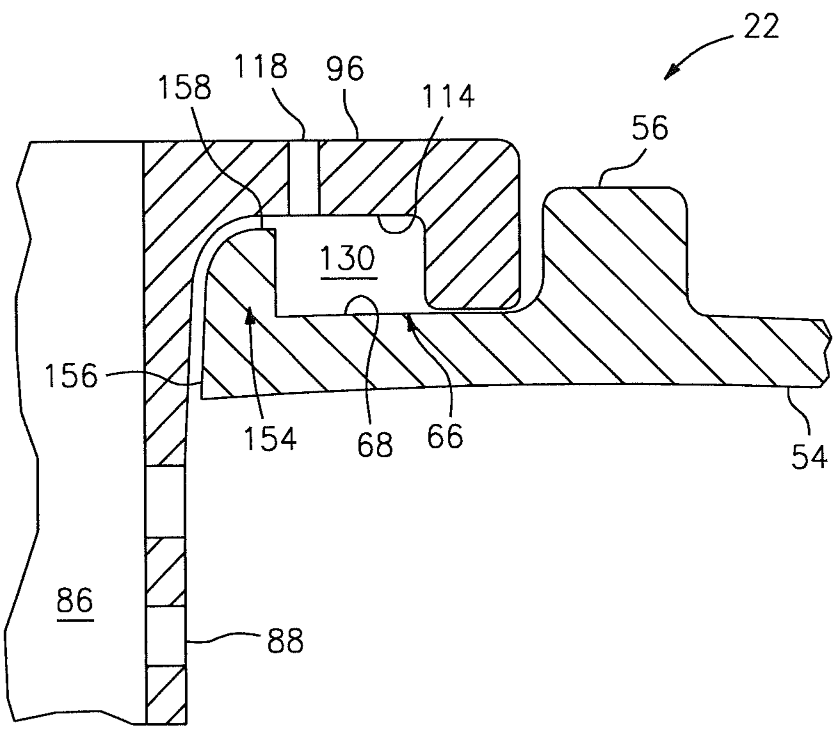
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FIG. 10

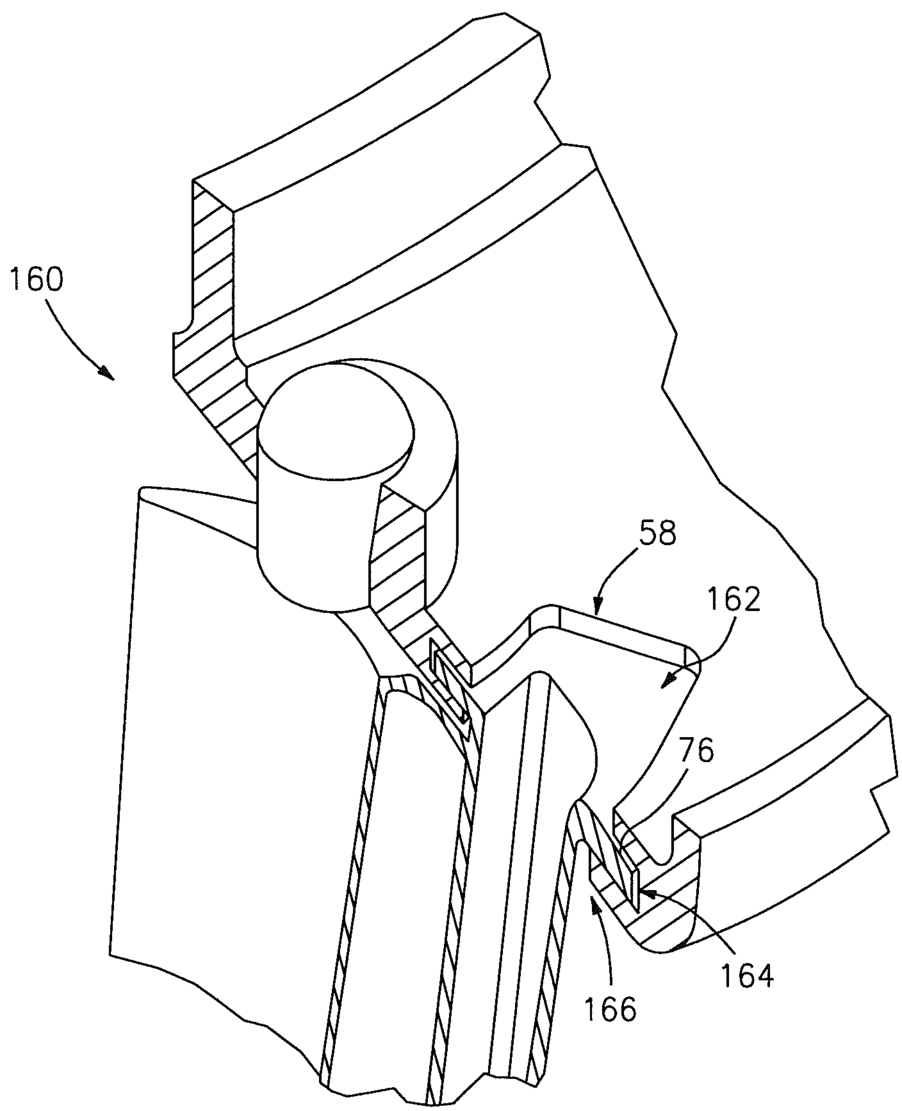

FIG. 11

TURBINE ENGINE VARIABLE AREA VANE

This invention was made with government support under Contract No. FA8650-09-D-2923-DO 0013 awarded by the United States Air Force. The government may have certain rights in the invention.

BACKGROUND OF THE INVENTION

1. Technical Field

The present invention relates generally to a turbine engine and, more particularly, to a variable area vane arrangement for a turbine engine.

2. Background Information

A typical turbine engine includes a plurality of engine sections such as, for example, a fan section, a compressor section, a combustor section and a turbine section. One or more of the engine sections may include a variable area vane arrangement. Such a vane arrangement may be configured to guide and/or adjust flow of core gas between adjacent rotor stages within the respective engine section. Alternatively, the vane arrangement may be configured to guide and/or adjust flow of core gas between the respective engine section and an adjacent (e.g., downstream) engine section.

A typical variable area vane arrangement includes a plurality of rotatable stator vanes extending between an outer radial stator vane platform and an inner radial stator vane platform. Outer radial ends of the stator vanes are rotatably connected to the outer radial stator vane platform with an outer shaft and a bearing. Inner radial ends of the stator vanes are rotatably connected to the inner radial stator vane platform with an inner shaft and a bearing. The outer shaft may include a bore that directs cooling air from a plenum, adjacent the outer radial stator vane platform, into a cavity within an airfoil of the respective stator vane. Airfoil cooling apertures may subsequently direct the cooling air out of the cavity to film cool the outer surfaces of the airfoil that are exposed to the core gas. To provide a sufficient quantity of the cooling air, the outer shaft bore typically has a relatively large diameter. As the diameter of the outer shaft bore increases, however, the size of the bearing also increases, which may significantly increase the weight, cost and complexity of the vane arrangement.

SUMMARY OF THE DISCLOSURE

According to an aspect of the invention, a turbine engine stator vane is provided that rotates about an axis, and includes an airfoil, a flange and a shaft. The airfoil extends axially between a first airfoil end and a second airfoil end. The airfoil includes a concave side surface, a convex side surface and a cavity. The concave and the convex side surfaces extend between an airfoil leading edge and an airfoil trailing edge. The cavity extends axially into the airfoil from a cavity inlet in an end surface at the second airfoil end. The flange is connected to the second airfoil end. The flange extends circumferentially around at least a portion of the cavity inlet, and radially away from the concave and the convex side surfaces to a distal flange edge. The shaft extends along the axis, and is connected to the second airfoil end.

According to another aspect of the invention, a variable area vane arrangement is provided that includes a stator vane first platform, a stator vane second platform having a vane aperture, and a stator vane that rotates about an axis. The stator vane includes an airfoil, a flange, a first shaft and a second shaft. The airfoil extends axially between a first airfoil end and a second airfoil end, and includes a concave side surface, a convex side surface and a cavity. The concave and the convex side surfaces extend between an airfoil leading edge and an airfoil trailing edge. The cavity extends axially into the airfoil from a cavity inlet in an end surface at the second airfoil end. The flange is connected to the second airfoil end and seated within the vane aperture. The flange extends circumferentially around at least a portion of the cavity inlet, and radially away from the concave and the convex side surfaces to a distal flange edge. The first shaft extends along the axis, and is connected to the second airfoil end and is rotatably connected to the second platform. The second shaft also extends along the axis, and rotatably connects the first airfoil end to the first platform.

The flange may extend radially from the leading edge to the distal flange edge.

The airfoil may include one or more cooling apertures that respectively extend from the cavity to the concave side surface, the convex side surface, the leading edge and/or the trailing edge.

The airfoil may include a second cavity that extends axially into the airfoil from a second cavity inlet in the end surface. The flange extends circumferentially around at least a portion of the second cavity inlet.

The flange may extend axially from the end surface to a cooling channel surface, and includes a lip that extends substantially along the distal flange edge. A cooling channel is provided that extends radially between the airfoil and the lip adjacent to the cooling channel surface. In an embodiment, the vane aperture includes a semi-annular shelf with a seal surface, and the cooling channel extends axially between the seal surface and the cooling channel surface. In another embodiment, the vane aperture also includes a shelf lip that extends along an inner radial edge of the shelf and axially into the cooling channel from the seal surface. One or more cooling apertures may extend axially through the flange, and are fluidly coupled with the cooling channel.

The flange may extend circumferentially around the cavity inlet between a first tab seal surface and a second tab seal surface, and the shaft is located adjacent to and between the first and the second tab seal surfaces. In an embodiment, the shaft includes a notch that extends circumferentially around the axis between the first and the second tab seal surfaces, and the notch includes a semi-annular seal surface. In another embodiment, a seal with a semi-annular seal body is provided that extends circumferentially between a first tab and a second tab. The seal body engages the semi-annular seal surface, the first tab engages the first tab seal surface, and the second tab engages the second tab seal surface.

The shaft may be a solid shaft or a hollow shaft.

A vane actuation element may be connected to the flange. The actuation element extends axially from the end surface to a distal actuation element end adapted to connect to a vane actuator.

A fixed stator vane may be connected between the first platform and the second platform.

The first platform may be one of a plurality of arcuate segments of an annular stator vane first platform, the second platform is one of a plurality of arcuate segments of an annular stator vane second platform, and the stator vane is one of a plurality of stator vanes rotatably connected to the annular stator vane first platform and the annular stator vane second platform.

The foregoing features and the operation of the invention will become more apparent in light of the following description and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective illustration of a variable area vane arrangement for a turbine engine;

FIG. **2** is a perspective illustration of a section of the vane arrangement of FIG. **1**;

FIG. **3** is another perspective illustration of a section of the vane arrangement of FIG. **1**;

FIG. **4** is a top view illustration of the vane arrangement of FIG. **3**;

FIG. **5** is a side-sectional illustration of a section of the vane arrangement of FIG. **3**;

FIG. **6** is a perspective illustration of a section of a rotatable stator vane configured with a seal;

FIG. **7** is a perspective illustration of the rotatable stator vane of FIG. **6** without the seal;

FIG. **8** is another perspective illustration of the rotatable stator vane of FIG. **6** without the seal;

FIG. **9** is another perspective illustration of a section of the vane arrangement of FIG. **1**;

FIG. **10** is a side-sectional illustration of a section of an alternative embodiment variable area vane arrangement for a turbine engine; and

FIG. **11** is a perspective illustration of a section of another alternative embodiment variable area vane arrangement for a turbine engine.

DETAILED DESCRIPTION OF THE INVENTION

FIG. **1** illustrates a variable area vane arrangement **20** for an engine section (e.g., a turbine section and/or a compressor section) of a turbine engine. FIG. **2** illustrates an enlarged section of the vane arrangement **20**. Referring to FIGS. **1** and **2**, the vane arrangement **20** may include a plurality of vane arrangement segments **22**.

Referring to FIG. **2**, one or more of the vane arrangement segments **22** includes a stator vane first platform **24** (e.g., an inner platform), a stator vane second platform **26** (e.g., an outer platform), at least one rotatable stator vane **28**, and an apparatus **30** (e.g., a rotatable feather seal) for sealing a gap between the second platform **26** and the rotatable stator vane **28**. One or more of the vane arrangement segments **22** may also include at least one fixed stator vane **32**.

The first platform **24** extends longitudinally between a first (e.g., upstream) platform end **34** and a second (e.g., downstream) platform end **36** (see FIG. **1**). The first platform **24** extends laterally and, for example, arcuately between a first platform side **38** and a second platform side **40**. The first platform **24** also extends between a first (e.g., inner) platform surface **42** and a second (e.g., outer, gas path) platform surface **44**.

The second platform **26** extends longitudinally between a first (e.g., upstream) platform end **46** and a second (e.g., downstream) platform end **48**. The second platform **26** extends laterally and, for example, arcuately between a first platform side **50** and a second platform side **52**. The second platform **26** also extends between a first (e.g., inner, gas path) platform surface **54** and a second (e.g., outer) platform surface **56**.

The second platform **26** includes one or more vane apertures such as, for example, a first vane aperture **58** and a second vane aperture **60**. The first vane aperture **58** may be located at the first platform side **50**, and the second vane aperture **60** may be located at the second platform side **52**. Each of the vane apertures **58**, **60** extends from the second platform surface **56** to the first platform surface **54**. Referring to FIGS. **3** to **5**, for example, the first vane aperture **58** may include a first aperture segment **62**, a second aperture segment **64**, a semi-annular aperture shelf **66** with a substantially flat, semi-annular sealing surface **68**, and a seal slot **70** (e.g., a feather seal slot). The first aperture segment **62** extends from the second platform surface **56** to the second aperture segment **64**, which extends to the first platform surface **54**. The aperture shelf **66** is defined at the intersection of the first aperture segment **62** and the second aperture segment **64**. The seal slot **70** extends into a sidewall of the first vane aperture **58** and, for example, is substantially axially aligned with the aperture shelf **66**. The second vane aperture **60** (see FIG. **2**) may have a similar configuration to that of the first vane aperture **58**. The second vane aperture **60**, for example, may include a first aperture segment, a second aperture segment, a semi-annular aperture shelf with a substantially flat, semi-annular sealing surface, and a seal slot (e.g., a feather seal slot).

The rotatable stator vane **28** includes a rotatable vane airfoil **72**, a shaft **74** and a flange **76**. Referring to FIG. **2**, the rotatable vane airfoil **72** extends axially between a first (e.g., inner) airfoil end **78** and a second (e.g., outer) airfoil end **80**. Referring now to FIGS. **3**, **6** and **7**, the rotatable vane airfoil **72** has a concave side surface **82**, a convex side surface **84**, one or more cavities **86**, and one or more airfoil cooling apertures **88**. The concave side surface **82** and the convex side surface **84** extend between an airfoil leading edge **90** and an airfoil trailing edge **92**. Each of the cavities **86** extends axially into the airfoil **72** from a respective cavity inlet **94** towards the first airfoil end **78** (see FIG. **2**). One or more of the cavity inlets **94** may be arranged in a first (e.g., outer) end surface **96** of the second airfoil end **80**. The airfoil cooling apertures **88** respectively extend from the cavities **86** to the concave side surface **82**, the convex side surface **84**, the leading edge **90**, and/or the trailing edge **92**.

The shaft **74** is connected to the second airfoil end **80**, and extends axially to a distal shaft end **98**. The shaft **74**, for example, extends along an axis **100** from a second (e.g., inner) end surface **102** of the second airfoil end **80** to the distal shaft end **98**. The shaft **74** is located a first distance from the airfoil leading edge **90**. The shaft **74** is located a second distance from the airfoil trailing edge **92** that is, for example, less than the first distance. Referring to FIG. **7**, the shaft **74** may include a circumferentially extending notch **104** with a semi-annular seal surface **106**.

The flange **76** is connected to the second airfoil end **80**. The flange **76** extends circumferentially around at least a portion of one or more of the cavity inlets **94** between, for example, an axially extending first tab seal surface **108** and an axially extending second tab seal surface **110**. The first tab seal surface **108** is located adjacent to a first end of the circumferentially extending notch **104**. The second tab seal surface **110** is located adjacent to a second end of the circumferentially extending notch **104**. The flange **76** extends radially from the concave side surface **82**, the convex side surface **84** and, for example, the leading edge **90** (see FIG. **8**) to a distal flange edge **112**. The flange **76** may also extend axially from the first end surface **96** to a cooling channel surface **114**.

Referring to FIGS. **5**, **7** and **8**, the flange **76** may include a flange lip **116** and/or one or more flange cooling apertures **118**. The flange lip **116** extends along the distal flange edge **112**, for example, between the first tab seal surface **108** and the second tab seal surface **110**. The flange lip **116** also extends axially from the cooling channel surface **114** to a platform seal surface **120** at a distal lip edge **122**. The flange cooling apertures **118** extend axially from the first end surface **96** to the cooling channel surface **114**. The flange cooling apertures **118** may be arranged proximate the concave side surface **82**, the convex side surface **84**, and/or the leading edge **90**.

Referring to FIGS. **6** and **7**, the seal **30** includes a substantially flat, semi-annular seal body **124** that extends circumferentially between a first tab **126** and a second tab **128**. The first tab **126** engages (e.g., sealingly connects to) the first tab seal surface **108**. The second tab **128** engages (e.g., sealingly connects to) the second tab seal surface **110**. The seal body **124** wraps partially around the shaft **74**, and engages (e.g., sealingly connects to) the semi-annular seal surface **106**.

Referring to FIGS. **3** to **5**, the rotatable stator vane **28** is mated with the first vane aperture **58**. The flange **76**, for example, is seated in the first aperture segment **62** and the platform seal surface **120** engages (e.g., sealingly connects to) the sealing surface **68** of the aperture shelf **66**. The seal body **124** is mated with (e.g., sealingly inserted into) the seal slot **70** to form a seal therebetween. Referring to FIGS. **5** and **8**, a cooling channel **130** extends radially between the airfoil **72** and the flange lip **116**. The cooling channel **130** extends axially between the sealing surface **68** and the cooling channel surface **114**. The cooling channel **130** also extends circumferentially between the first tab **126** and the second tab **128** (see FIG. **6**).

Referring to FIG. **2**, the rotatable vane airfoil **72** extends between and is rotatably connected to the first platform **24** and the second platform **26**. The shaft **74**, for example, is rotatably connected to the second platform **26** by a bearing **132** (e.g., a pillow block bearing, etc.). Referring to FIG. **9**, a second shaft **136** connected to the first airfoil end **78** may be rotatably connected to the first platform **24** by a bearing **138** (e.g., a cartridge bearing, etc.). Examples of such rotatable connections are disclosed in U.S. Publication No. 2009/0097966, which is hereby incorporated by reference, and assigned to the assignee of the present invention. Examples of other types of rotatable connections are disclosed in U.S. Pat. Nos. 8,105,019 and 8,007,229, each of which is hereby incorporated herein by reference, and assigned to the assignee of the present invention. The present invention, of course, is not limited to any particular rotatable connection types and/or configurations between the rotatable stator vane **28** and the first and second platforms **24** and **26**.

Referring to FIGS. **1** and **2**, the fixed stator vane **32** includes a fixed vane airfoil **140** that extends axially between a first (e.g., inner) airfoil end **142** and a second (e.g., outer) airfoil end **144**. The fixed vane airfoil **140** includes a concave side surface and a convex side surface, where both surfaces extend between an airfoil leading edge and an airfoil trailing edge (not shown). The first airfoil end **142** is fixedly connected to (e.g., integral with) the second platform surface **44** of the first platform **24**. The second airfoil end **144** is fixedly connected to (e.g., integral with) the first platform surface **54** of the second platform **26**.

Each of the vane arrangement segments **22** is connected between respective adjacent vane arrangement segments **22** to form the variable area vane arrangement **20**. The first platform side **38** of each of the first platforms **24**, for example, is connected to a respective second platform side **40** to form an annular stator vane first platform **146**. Each of the rotatable stator vanes **28** is mated with a respective second vane aperture **60**, for example, in a similar manner as described above with respect to the mating of the rotatable stator vane **28** with the first vane aperture **58**. The first platform side **50** of each of the second platforms **26** is connected to a respective second platform side **52** to form an annular stator vane second platform **148**.

The variable area vane arrangement **20** may be arranged, in some embodiments, between adjacent rotor stages (e.g., adjacent turbine or compressor stages) of the engine section. The variable area vane arrangement **20** may be arranged, in other embodiments, within the respective engine section adjacent another (e.g., downstream) engine section.

The rotatable stator vanes **28** may be respectively rotated about the axes **100** to guide gas through the variable area vane arrangement **20** according to a certain trajectory. The rotatable stator vanes **28** may also or alternatively be rotated to adjust flow of the gas through the variable area vane arrangement **20**. Referring to FIGS. **3** to **5**, each of the platform seal surfaces **120** may respectively maintain the seal with the sealing surface **68** of the aperture shelf **66** during the rotation. In addition, each of the seals **30** may respectively maintain the seals with the semi-annular seal surface **106** (see FIG. **7**), the seal slot **70**, and the tab seal surfaces **108** and **110**. In this manner, the flange **76** and the seal **30** may significantly reduce and/or eliminate gas leakage through the gap between the rotatable stator vane **28** and the annular stator vane second platform **148** (see FIG. **2**) during the rotation of the respective rotatable stator vane **28**.

The cavity inlets **94** respectively direct cooling air from a plenum adjacent the second platform surface **56** into the cavities **86**. The airfoil cooling apertures **88** subsequently direct this cooling air out of the airfoil **72** to cool (e.g., film cool) the concave side surface **82**, the convex side surface **84**, the leading edge **90**, and/or the trailing edge **92**. When the rotatable stator vane **28** is rotated such that the gap between a wall of the second aperture segment **64** and the airfoil **72** is small (as shown in FIGS. **5** and **10**), the flange cooling apertures **118** direct cooling air from the plenum into the cooling channel **130** to cool (e.g., impingement cool) the aperture shelf **66**. This cooling air may subsequently leak through the gap and/or through film cooling holes (not shown) arranged in the aperture shelf **66** to cool (e.g., film cool) the first platform surface **54**. As the rotatable stator vane **28** rotates in the opposite direction, the gap may become larger and the cooling channel surface **114** and/or the flange cooling apertures **118** may become exposed to the gaspath. In this instance, the flange cooling apertures **118** no longer provide impingement cooling to aperture shelf **66**, but instead provide film cooling for surface **114**.

Referring to FIG. **2**, in some embodiments, one or more of the rotatable stator vanes **28** may include a vane actuation element **150** connected to a respective flange **76**. The actuation element **150** may be configured as a cylindrical shaft, and extend axially from the first end surface **96** to a distal actuation element end **152**. The distal actuation element end **152** is adapted to connect to a vane actuator (not shown) such as, for example, a unison ring. An example of a unison ring is disclosed in U.S. Pat. No. 8,092,157, which is hereby incorporated herein by reference, and which is assigned to the assignee of the present invention. The present invention, of course, is not limited to any particular type or configuration of vane actuation elements and/or vane actuators. In other embodiments, for example, the actuation element may be configured as a linkage arm connected to the distal end of the shaft **74**.

Referring to FIG. **10**, in some embodiments, the aperture shelf **66** may include a shelf lip **154** that extends along a distal shelf edge **156**. The shelf lip **154** extends axially from the sealing surface **68** to a distal lip edge **158**, which may be separated from the cooling channel surface **114** by a leakage gap.

A person of skill in the art will recognize the shape, size and number of one or more of the cavities, cavity inlets, airfoil cooling apertures and/or flange cooling apertures may vary depending upon the size and/or design of the variable area vane arrangement. In some embodiments, for example, some or all of the cavities within a respective airfoil may be interconnected. In other embodiments, the cavities within a respective airfoil may be fluidly discrete. In some embodiments, the cavity inlets, the airfoil cooling apertures and/or the flange cooling apertures may have elongated (e.g., rectangular, oval, elliptical, etc.) cross-sectional geometries. In other embodiments, the cavity inlets, the airfoil cooling apertures and/or the flange cooling may have circular cross-sectional geometries. In still other embodiments, the cavity inlets, the airfoil cooling apertures and/or the flange cooling may have flared geometries. The present invention therefore is not limited to the cavities, cavity inlets, airfoil cooling apertures and/or flange cooling apertures described above or illustrated in the drawings.

FIG. **11** illustrates a section of an alternative embodiment vane arrangement segment **160**. In contrast to the vane arrangement segment **22** of FIG. **3**, each vane aperture **58**, **60** of the vane arrangement segment **160** includes a first aperture segment **162**, a second aperture segment **164** and a third aperture segment **166**. The second aperture segment **164** defines a slot, between the first and third aperture segments **162** and **166**, that receives the flange **76**.

While various embodiments of the present invention have been disclosed, it will be apparent to those of ordinary skill in the art that many more embodiments and implementations are possible within the scope of the invention. For example, the present invention as described herein includes several aspects and embodiments that include particular features. Although these features may be described individually, it is within the scope of the present invention that some or all of these features may be combined within any one of the aspects and remain within the scope of the invention. Accordingly, the present invention is not to be restricted except in light of the attached claims and their equivalents.

What is claimed is:

1. A turbine engine stator vane that rotates about an axis, comprising:
- an airfoil extending axially between a first airfoil end and a second airfoil end, and comprising a concave side surface, a convex side surface and a cavity, wherein the concave and the convex side surfaces extend between an airfoil leading edge and an airfoil trailing edge, and the cavity extends axially into the airfoil from a cavity inlet in an end surface at the second airfoil end;
- a flange connected to the second airfoil end, wherein the flange extends circumferentially around at least a portion of the cavity inlet, and radially away from the concave and the convex side surfaces to a distal flange edge, wherein the flange has a non-circular cross-sectional geometry which lies in a plane that is perpendicular to the axis of the stator vane; and
- a shaft extending along the axis, and connected to the second airfoil end.

2. The stator vane of claim **1**, wherein the flange further extends radially from leading edge to the distal flange edge.

3. The stator vane of claim **1**, wherein the airfoil further comprises one or more cooling apertures that respectively extend from the cavity to at least one of the concave side surface, the convex side surface, the leading edge and the trailing edge.

4. The stator vane of claim **1**, wherein the airfoil further comprises a second cavity extending axially into the airfoil from a second cavity inlet in the end surface, and wherein the flange extends circumferentially around at least a portion of the second cavity inlet.

5. A turbine engine stator vane that rotates about an axis, comprising:
- an airfoil extending axially between a first airfoil end and a second airfoil end, and comprising a concave side surface, a convex side surface and a cavity, wherein the concave and the convex side surfaces extend between an airfoil leading edge and an airfoil trailing edge, and the cavity extends axially into the airfoil from a cavity inlet in an end surface at the second airfoil end;
- a flange connected to the second airfoil end, wherein the flange extends circumferentially around at least a portion of the cavity inlet, and radially away from the concave and the convex side surfaces to a distal flange edge; and
- a shaft extending along the axis, and connected to the second airfoil end;
- wherein the flange extends axially from the end surface to a cooling channel surface, and comprises a lip that extends substantially along the distal flange edge, and wherein a cooling channel extends radially between the airfoil and the lip adjacent to the cooling channel surface.

6. The stator vane of claim **5**, further comprising one or more cooling apertures extending axially through the flange, and fluidly coupled with the cooling channel.

7. A turbine engine stator vane that rotates about an axis, comprising:
- an airfoil extending axially between a first airfoil end and a second airfoil end, and comprising a concave side surface, a convex side surface and a cavity, wherein the concave and the convex side surfaces extend between an airfoil leading edge and an airfoil trailing edge, and the cavity extends axially into the airfoil from a cavity inlet in an end surface at the second airfoil end;
- a flange connected to the second airfoil end, wherein the flange extends circumferentially around at least a portion of the cavity inlet, and radially away from the concave and the convex side surfaces to a distal flange edge; and
- a shaft extending along the axis, and connected to the second airfoil end;
- wherein the flange extends circumferentially around the cavity inlet between a first tab seal surface and a second tab seal surface, and the shaft is located adjacent to and between the first and the second tab seal surfaces.

8. The stator vane of claim **7**, wherein the shaft comprises a notch that extends circumferentially around the axis between the first and the second tab seal surfaces, and the notch comprises a semi-annular seal surface.

9. The stator vane of claim **8**, further comprising a seal with a semi-annular seal body that extends circumferentially between a first tab and a second tab, wherein the seal body engages the semi-annular seal surface, the first tab engages the first tab seal surface, and the second tab engages the second tab seal surface.

10. The stator vane of claim **1**, wherein the shaft comprises a solid shaft.

11. The stator vane of claim **1**, further comprising a second shaft that extends along the axis, and is connected to the first airfoil end.

12. The stator vane of claim **1**, further comprising a vane actuation element connected to the flange, wherein the actuation element extends axially from the end surface to a distal actuation element end adapted to connect to a vane actuator.

13. A variable area vane arrangement, comprising:
- a stator vane first platform;
- a stator vane second platform comprising a vane aperture; and
- a stator vane that rotates about an axis, the stator vane comprising
  - an airfoil extending axially between a first airfoil end and a second airfoil end, and comprising a concave

side surface, a convex side surface and a cavity, wherein the concave and the convex side surfaces extend between an airfoil leading edge and an airfoil trailing edge, and the cavity extends axially into the airfoil from a cavity inlet in an end surface at the second airfoil end;

a flange connected to the second airfoil end and seated within the vane aperture, wherein the flange extends circumferentially around at least a portion of the cavity inlet, and radially away from the concave and the convex side surfaces to a distal flange edge, and wherein the flange has a non-circular cross-sectional geometry which lies in a plane that is perpendicular to the axis of the stator vane;

a first shaft extending along the axis, wherein the first shaft is connected to the second airfoil end and is rotatably connected to the second platform; and

a second shaft extending along the axis, wherein the second shaft rotatably connects the first airfoil end to the first platform;

wherein a gas path is formed between the first platform and the second platform, and wherein the second platform is disposed between the gas path and the flange.

14. The vane arrangement of claim **13**, wherein the flange further extends radially from the leading edge to the distal flange edge.

15. The vane arrangement of claim **13**, wherein the airfoil further comprises one or more cooling apertures that respectively extend from the cavity to at least one of the concave side surface, the convex side surface, the leading edge and the trailing edge.

16. A variable area vane arrangement, comprising:

a stator vane first platform;

a stator vane second platform comprising a vane aperture; and

a stator vane that rotates about an axis, the stator vane comprising

an airfoil extending axially between a first airfoil end and a second airfoil end, and comprising a concave side surface, a convex side surface and a cavity, wherein the concave and the convex side surfaces extend between an airfoil leading edge and an airfoil trailing edge, and the cavity extends axially into the airfoil from a cavity inlet in an end surface at the second airfoil end;

a flange connected to the second airfoil end and seated within the vane aperture, wherein the flange extends circumferentially around at least a portion of the cavity inlet, and radially away from the concave and the convex side surfaces to a distal flange edge;

a first shaft extending along the axis, wherein the first shaft is connected to the second airfoil end and is rotatably connected to the second platform; and

a second shaft extending along the axis, wherein the second shaft rotatably connects the first airfoil end to the first platform;

wherein the vane aperture comprises a semi-annular shelf with a seal surface;

wherein the flange extends axially from the end surface to a cooling channel surface, and comprises a flange lip that extends substantially along the distal flange edge and is engaged with the seal surface; and

wherein a cooling channel extends radially between the airfoil and the flange lip, and axially between the seal surface and the cooling channel surface.

17. The vane arrangement of claim **16**, further comprising one or more cooling apertures extending axially through the flange, and fluidly coupled with the cooling channel.

18. The vane arrangement of claim **16**, wherein the vane aperture further comprises a shelf lip that extends along an inner radial edge of the shelf and axially into the cooling channel from the seal surface.

19. The vane arrangement of claim **13**, further comprising a fixed stator vane connected between the first platform and the second platform.

20. The vane arrangement of claim **13**, wherein

the first platform is one of a plurality of arcuate segments of an annular stator vane first platform;

the second platform is one of a plurality of arcuate segments of an annular stator vane second platform;

the stator vane is one of a plurality of stator vanes rotatably connected to the annular stator vane first platform and the annular stator vane second platform.

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